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Search for Top with DØ Detector in Dilepton Channel

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ABSTRACT

Preliminary results from a search for high mass $t\bar{t}$ quark pair production in $p\bar{p}$ collisions at $\sqrt{s} = 1.8$ TeV with the DØ detector in the ee+jets, $e\mu$+jets, and $\mu\mu$+jets decay channels are presented. No conclusive evidence for top quark production for an integrated luminosity of 13.5 ± 1.6 pb^{-1} is observed.

1. Introduction

At the Fermilab Tevatron $p\bar{p}$ center of mass energy the Standard Model top quark t with the mass m_t greater than about 90 GeV/c^2 is expected to be produced mainly in $t\bar{t}$ pairs through the quark-quark annihilation with some contribution from gluon-gluon fusion. The gluon-gluon contribution decreases as m_t increases.[1] Once m_t is greater than the mass of the W-boson the top quark is expected to decay via the weak charged current ($t \rightarrow W^+ b$) and the event signatures follow from the W branching fractions.

DØ has published a lower limit for m_t of 131 GeV/c^2 at 95% confidence level.[2] The prediction for the top mass based on the precision electroweak LEP measurements[3] is $m_t = 172^{+13+18}_{-14-20}$ GeV/c^2. The CDF evidence for the top quark indicates its mass to be[4] $m_t = 174 \pm 10^{+13}_{-12}$ GeV/c^2

The analysis presented in this paper is focused on the top mass above 120 GeV/c^2 and includes a new channel $\mu\mu$ which was not used in the previous analysis.[2] The dilepton channels considered: ee, $e\mu$, and $\mu\mu$ constitute 1/81, 2/81, and 1/81 of all $t\bar{t}$ events respectively. The contributions from $e\tau$, $\mu\tau$, and $\tau\tau$ channels having the same signatures as ee, $e\mu$, and $\mu\mu$ are also taken into account in the event yields. The lepton plus jets channels are discussed in complementary DØ papers,[5,6] where also the cross-section results are summarized.[6]

2. DØ Detector and Data Sample

The DØ detector[7] is based on a hermetic, high granularity, high resolution, compensating liquid Argon – depleted Uranium calorimeter. The calorimeter is surrounded by a hermetic muon system which has one super layer of proportional drift chambers before and two super layers of chambers behind magnetized iron toroids. The central tracking system placed between the beam pipe and the calorimeter consists of a vertex proportional chamber, transition radiation detector and central, and forward drift

chambers. There is no central magnetic field. The calorimeter energy resolutions can be parametrized as $\sigma(E)/E \approx A/\sqrt{E}$ (E in GeV), where $A=0.15$ for electrons, and $A=0.80$ for jets. The muon momentum resolution is $\sigma(1/p) \approx 0.2/p + 0.01$ GeV/c^{-1}. For minimum bias events, the resolution for each component of the missing transverse energy $\not{E}_T$ is about 1.1 GeV$+0.02\times(\Sigma E_T)$, where ΣE_T is the scalar sum of all the transverse energy E_T in the calorimeter.

The data sample analyzed was collected during the Fermilab Tevatron Collider run 1992/93 and has a corresponding luminosity of 13.5 ± 1.6 pb^{-1} for the ee and $e\mu$ channels, and 9.8 ± 1.2 pb^{-1} for the $\mu\mu$ channel.

3. Lepton Identification

All the $t\bar{t}$ dilepton decay channels are characterized by the presence of two high transverse momentum isolated leptons, large missing transverse momentum and significant jet activity. Once appropriate lepton identification and kinematic cuts are applied one can expect a good signal to background ratio and a good efficiency.

3.1. Electron Identification

Electrons are identified as energy clusters in the electromagnetic calorimeter within the pseudorapidity region of $|\eta| < 2.5$. The clusters are required to have at least 90% of their total energy in the electromagnetic part of the calorimeter. The longitudinal and transverse cluster profile has to be consistent with the shape of the electromagnetic shower initiated by an electron.[8] The isolation requirement is $(E_{TOT}^{0.4} - E_{EM}^{0.2})/E_{EM}^{0.2} < 0.1$ where $E_{TOT}^{0.4}$ and $E_{EM}^{0.2}$ are the total and electromagnetic cluster energy contained within the cone of $\mathcal{R} < 0.4$ and $\mathcal{R} < 0.2$ respectively and $\mathcal{R}$ is defined as $\mathcal{R} = \sqrt{(\Delta\phi)^2 + (\Delta\eta)^2}$. It is also required that there is a central detector track coming from the interaction vertex which is matched with each cluster. In the case of the ee channel, the track has to have the corresponding energy deposition in the drift chambers which is consistent with that of a single charged particle.

3.2. Muon Identification

Muons are identified as tracks in the muon drift chambers after penetrating through 13 to 19 interaction lengths of calorimeter and muon toroids. It is required that there is an associated minimum ionizing deposition of at least 0.5 GeV in the calorimeter along the path of the muon if there is a central track matching the muon track, and a deposition of at least 1.5 GeV if there is not a central detector track which matches the muon track. To reject cosmic rays, no track or hits consistent with a track back-to-back in η and ϕ to the considered muon are allowed. It is required that the magnetic field integrated over the path of the muon is greater than 1.83 Tm in order to assure good momentum determination. In case of the $e\mu$ channel, the isolation is imposed by rejecting muons for which there is a jet with the transverse energy E_T greater than 8 GeV within the cone of $\mathcal{R} < 0.5$ or for which there is an energy deposit of 4 GeV or more in an annular cone of $0.2 < \mathcal{R} < 0.4$ around the muon direction. For the $\mu\mu$ channel, to impose isolation, muons with the transverse momentum relative to the nearest jet smaller than 5 GeV/c are rejected. For the $e\mu$ channel, all muons within pseudorapidity region of $|\eta| < 1.7$ are considered. For the $\mu\mu$ channel, central muons ($|\eta| < 1.1$) are used.

4. Analysis of Dilepton Channels and Background Processes

4.1. $\mu\mu$ channel

This is a new channel which was not included in the previous analysis.[2] The trigger for this channel requires a muon candidate with the transverse momentum p_T greater than 14 GeV/c and a jet candidate with $E_T > 15$ GeV. The offline cuts demand two muons, each with $p_T > 15$ GeV/c. To reject background processes, two jets with $E_T > 15$ GeV are required. Dimuon invariant mass $M_{\mu\mu}$ is required to be greater than 10 GeV/c^2 to remove J/Ψ or Ψ' events. $Z^0 \rightarrow \mu\mu$ events are rejected by demanding that the angle between $\not{E}_T$ and the leading muon to be smaller than 165° (165°) for two (three) layer muon tracks. Since the calorimeter missing transverse energy $\not{E}_T^{cal}$ is an independent measure of the transverse momentum of the muon pair, the events are rejected if $\Delta\phi(\not{E}_T^{cal}, \vec{p}_T^{\mu\mu}) > 30°$ where $\Delta\phi$ is the azimuthal opening angle. Further rejection of the $Z^0 \rightarrow \mu\mu$ events is achieved by the cut $\not{E}_T > 40$ GeV when $\Delta\phi(\vec{p}_T^{\mu_1}, \vec{p}_T^{\mu_2}) > 140°$. No events remain after all the cuts. Very good agreement between the data and the dominant background process $Z^0 \rightarrow \mu\mu$ is seen at all the stages of the analysis. The predicted number of $Z^0 \rightarrow \mu\mu$ events is 0.28 ± 0.05. The event yields for this and for the other channels, for the data, $t\bar{t}$ Monte Carlo and for the background processes are summarized in table 1. The event yields for the $t\bar{t}$ production were calculated using central value of the $t\bar{t}$ cross-section.[1] The number of background events coming from processes of the same signature as the process under study was predicted using Monte Carlo simulations. The errors quoted are statistical and systematic. In addition to the quoted errors there is an additional normalization error due to the 12% uncertainty in the value of the integrated luminosity.

4.2. ee channel

The trigger used in this channel is a logical OR of triggers demanding one electron candidate with $E_T > 20$ GeV, or two electron candidates with $E_T > 10$ GeV, or an electron candidate with $E_T > 20$ GeV and $\not{E}_T > 20$ GeV, or one electron candidate with $E_T > 15$ GeV and $\not{E}_T > 20$ GeV and two jets with $E_T > 16$ GeV. The offline selection cuts require two electrons, each with $E_T > 20$ GeV, $\not{E}_T > 25$ GeV and two jets with $E_T > 15$ GeV. $Z^0 \rightarrow ee$ events are rejected by demanding $|M_Z - M_{ee}| > 12$ GeV/c^2 if $\not{E}_T < 40$ GeV. No events remain after all the cuts. The complete event yields can be found in table 1. After all cuts, the remaining dominant background processes are $Z^0 \rightarrow \tau\tau \rightarrow ee$ and $Z^0 \rightarrow ee$. There is also an instrumental background when a jet is misidentified as an electron in the W+jets events. The probability of a jet faking an electron was estimated using an independent jet data sample.

4.3. $e\mu$ channel

The trigger used in this channel is also a logical OR of triggers requiring one electron candidate with $E_T > 7$ GeV and one muon candidate with $p_T > 5$ GeV/c, or a muon candidate with $p_T > 14$ GeV/c and a jet candidate with $E_T > 15$ GeV, or an electron candidate with $E_T > 15$ GeV and $\not{E}_T > 20$ GeV and two jets with $E_T > 16$ GeV. The offline kinematic cuts require muon $p_T > 12$ GeV/c, electron $E_T > 15$ GeV, $\not{E}_T > 10$ GeV, and two jets with $E_T > 15$ GeV. To reject W($\mu\nu_\mu$)+jets

events it is required that $\not{E}_T^{cal} > 20$ GeV. The $\Delta R_{e\mu} > 0.25$ cut is used to remove muon bremsstrahlung events. One event survives all the cuts. This is the same remarkable event which was found in the previous analysis. The event is characterized by two very high p_T leptons. Figure 1a shows muon $1/p_T$ versus electron E_T for the data before the two jet cut is applied. The surviving event is marked by a $\star$. Figure 1b shows the corresponding Monte Carlo distribution. The event yields are summarized in table 1. The remaining dominant background processes are $Z^0 \rightarrow \tau\tau \rightarrow e\mu$ and $W(\mu\nu_\mu)$+jets with one jet misidentified as an electron.
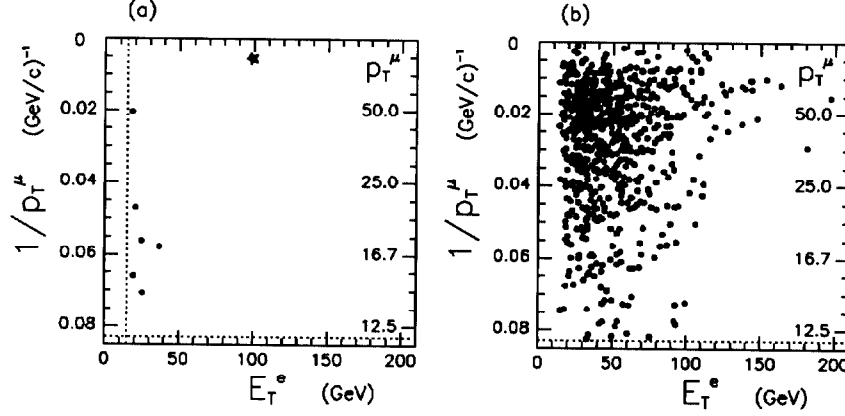

Fig. 1. Muon $1/p_T$ versus electron E_T for the $e\mu$ channel; a) Data 13.5 pb^{-1}, b) 170 GeV/c^2 $t\bar{t}$ Monte Carlo 21.3 fb^{-1}.

Table 1. Summary of event yields. The errors quoted are statistical and systematic. In addition to the quoted errors there is an additional normalization error due to the 12% uncertainty in the value of the integrated luminosity.

	$e\mu$	ee	$\mu\mu$
Luminosity [pb^{-1}]	13.5 ± 1.6	13.5 ± 1.6	9.8 ± 1.2
$t\bar{t}$ MC 140 GeV/c^2	0.72 ± 0.16	0.41 ± 0.07	0.24 ± 0.05
160 GeV/c^2	0.40 ± 0.09	0.22 ± 0.04	0.12 ± 0.02
180 GeV/c^2	0.23 ± 0.05	0.12 ± 0.02	0.06 ± 0.01
Data	1	0	0
Background	0.27 ± 0.09	0.16 ± 0.07	0.33 ± 0.06

5. Conclusions

DØ has performed a search for high mass $t\bar{t}$ decays into the three dilepton decay modes: $e\mu$+jets, ee+jets, and $\mu\mu$+jets. One event survives in the $e\mu$ channel. This is the same event as found in the original DØ analysis.[2] No candidates are found in the ee and $\mu\mu$ channels. Since the number of expected background events is consistent with the one event seen, it is concluded that no significant $t\bar{t}$ signal is observed. The results are preliminary.

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